145. Tephrodornis affinis, Blyth.

Peculiar to Ceylon, where it affects wooded grass lands; it is not uncommon about Jaffna, Colombo and Kandy. It is migratory, and appears in October. The iris of this species is a greenish yellow.

[To be continued.]

XIV.—*On the Mechanism of Aquatic Respiration and on the Structure of the Organs of Breathing in Invertebrate Animals.* By Thomas Williams, M.D. Lond., Licentiate of the Royal College of Physicians, formerly Demonstrator on Structural Anatomy at Guy's Hospital, and now of Swansea.

[Continued from vol. xii. p. 408.]

Articulata.—The annulose are most naturally succeeded by the articulate classes. The word 'annulose' differs in signification not more from the word 'articulate,' than in structure the annulose differs from the articulate animal. In the former a mechanically perfect *joint* never occurs. An 'articulation,' complete in all its mechanical appliances, is not produced in the animal kingdom below the Myriapod. The feet and tentacles of the Annelid, the spines and hard appendages of the Echinoderm, the soft processes of the Medusan, and the feelers of the Zoophyte are equally remote in construction from the leg of the insect or the claw of the crab. A '*joint*' is the symbol of organic superiority: it is not an arbitrary symbol; it is a unit in an *assemblage* of signs which proclaim a new and higher combination in the arrangements which constitute 'life.' At this limit in the animal series, the fluids and the solids of the organism undergo a signal exaltation of standard. The system of the chylaqueous fluid exists no longer in the adult organism,—it is present only in the embryonic. It is supplanted by that of the blood-proper. This capital fact supplies the material wherewith the physiologist forges the golden key which is capable of unlocking treasures long hidden from the eye of science. Coincidentally with *the joint*, at the frontier of the articulate subkingdom, there occurs a heart to circulate the blood, fibrine, and with it an order of floating corpuscles more highly organized in the fluids; a wondrous development of the muscular apparatus, striæ in the muscle-cell, a rapid increase in the dimensions of the cephalic ganglia, and in those of the organs of the special senses. It is here, in the history of the reproductive system, that the dicœcious character is first unquestionably assumed. These are note-worthy events in the ascensive march of organic architecture! *Why*, at

this particular link in the chain, are these events declared? How are they to be explained? Is it *necessary* in the scheme of creation that the Annelid should chronologically antecede the Myriapod? Are the fluids of the Annelid *plus* fibrine suddenly invested with such new building capacity as to be enabled to construct a Myriapod? The æra will assuredly arrive when organic science will satisfactorily answer such transcendental questions; there repose, beneath the curtain of the theories of spontaneous generation, specific transmutation, progressive development, &c., truths more recondite than any yet projected by the genius of the author of 'The Vestiges,' &c., or defended by the ingenuity of his countless reviewers.

The Myriapod is the lowest articulate animal, the Annelid the highest annulose: though constituting juxtaposed classes, they are yet divided by deep differential characters. The circulating system of the articulated animal is distinguished by one remarkable fact: only the *central* (dorsal) vessel enjoys the power of contracting and dilating; *every other* part of the circulatory apparatus is *passive*. The *supra-spinal vessel* in the Myriapod and the insect is *not pulsatile*; it is like the abdominal aorta in fishes. It is separated from the contractile centre by the intervention of narrow branches, the aortic arches, which embrace the œsophagus. The pulse-wave imparted to the fluid current by the ventricular action of the dorsal vessel is *broken* by these straitened tubes. The system of the branchial capillaries in the fish converts the saltatory manner in which the blood moves in the interval between them and the heart into a continuous non-pulsatile current. Thus the velocity of the current, and the force with which it travels, are reduced. A slackened course is impressed upon the blood-stream in every part of the body. From these anatomical facts will hereafter flow physiological consequences of great importance; they will unriddle the arcana of the *second* stage of respiration. The parietes of the peripheral channels, though undoubtedly constituting independent membranes, are adherent externally to the solid structures amid which they penetrate. In this particular they differ strikingly from the corresponding parts of the true-blood system of the Annelid. In the latter case, *every* vessel, the minutest and the largest, is detached from all other structures, appearing everywhere in form of independent systolising and diastolising tubes.

The *dorsal* vessel of the articulate animal is much more perfect, viewed as an hydraulic instrument of propulsion, than that of the Annelid. In a few species of Annelids, indeed, a cordiform development of this vessel occurs; it is, notwithstanding, little distinguished from the rest of the apparatus; centralization is not required. Every segment of the system, periphery and

centre, is actively operative in circulating the contents. In the instance of the articulate animal the mechanical conditions are different: the dorsal vessel *alone* is the active instrument of circulation.

The circumferential segments of the system *cannot* contract upon the contained fluid; the central organ therefore in this class is invested with additional strength; it is adapted for more powerful work. In its peripheric parts the circulatory apparatus of the articulate animal may be described as inferior to the analogous divisions of that of the Annelid. The conditions are reversed with reference to the centres. This character is not restricted to the air-breathing or tracheary Articulata; it prevails amongst the Crustacea. From Hunter to Newport this question has formed an arena of microscopic controversy:—are the vessels provided with separate and independent coats, or does the blood only traverse fortuitous channels in the "cellular membrane" of the solids? It is not devoid of interest, in the study of the *material conditions* of solid nutrition: it is not difficult of solution: it will be afterwards answered in detail. *No* channel through which *chylaqueous fluid* circulates is contractile. In no invertebrate animal, from the highest Annelid to the Zoophyte, does this anatomical character know an exception. It is *this* character which is extended to the anatomical disposition of the blood-tubes in the Articulata; it will be subsequently shown to belong equally to the circulatory system of the Mollusca. Although the fluids of the Articulate and Molluscan organisms represent true blood, the conduits through which it moves are not detached and independent structures. Although *more* complex and *more* raised in vital standard than the chylaqueous fluid of the Annelid and the Echinoderm, the blood of the Articulata and Mollusca is *less* complex and *less* raised in the scale of composition than that of vertebrated animals. It is thus easy to demonstrate that there obtains a direct and constant relation between the vital standard and chemical composition of the living fluids, and the anatomical characters of the tubular apparatus in which they perform their circulatory orbits. These facts have especial reference to the theory of respiration afterwards to be propounded.

The muscular system of the Articulata, as compared with that of the Annulose classes, manifests features of great superiority. The muscle-cell is more densely charged with fibrinous contents: the property of contractility is far higher in degree. The ceaseless activity of these animals flows from their remarkable muscularity. It is mechanically obvious that such a powerful muscular system as that of the Articulata presupposes an apparatus of fixed solids on which to act, and through which to pro-

duce mechanical results. Contemporaneously with this system accordingly appears the dermal skeleton of these classes. It is quite certain that such a highly developed state of the muscle-system as that which exists in the articulated animal *implies of necessity** the presence of a considerable proportion of fibrine in the blood. The production of *fibrine* in the fluids supposes a high standard of respiration, and a correspondently developed nervous system.

Of these several events, which takes the *lead*? Is it possible that an increase in the complexity of solid systems, the integumentary, the nervous, and the muscular, can *go before* the increasing complexity which occurs at this stage in the zoological series in the composition of the fluids? The question involves the absurdity of conceiving an effect without a cause, a sequence without an antecedence. Nature makes first the mortar, *then* builds; the fluids are first prepared, *then* the superstructure of the solids is raised.

The function of respiration always, in every animal, is inseparable from the blood-making physiological actions. It is commonly supposed that it is with the system of *the fluids* that the office of breathing immediately connects itself. Extraordinary facts will be afterwards adduced which will render this supposition no longer exclusively tenable. The tubular apparatus of the fluids evolves itself at some point or other of its periphery, such that the amount of oxygen received shall be proportional, not to the abstract *bulk* of that fluid, but to its vital composition. A very small *vertebrated* animal weighing fivefold *less* than a given *in*vertebrated animal, will consume in equal times fiftyfold more oxygen than the latter. 'Respiration,' therefore, is not an isolated physiological act, separable physically and dynamically from that complex assemblage of events which conspire in the maintenance of the living organism: it is an integer in the arithmetic sum of life. Its real value can only be determined by a study of it in its connections. Given the vital and chemical composition of the fluids, to estimate the proportion of oxygen demanded by any appointed organism? The problem is not empirical; it is scientific in the highest degree. It is an absolute rule in the physics of organization, that the structure and the function are directly proportional. An imperfect instrument can only produce imperfect results. The complex fluids and highly organized solids of the articulated animal render indispensable the provision of an *adequate* machinery for the inhalation of the vivifying principle. Thus then are

* See the author's papers "On the Blood," now being published in the British and Foreign Medical and Chirurgical Review, for a full exposition of this subject.

traced irrefutably the physiological circumstances which *necessitate* at this limit in the scale a new order of respiratory organs. The object is inimitably accomplished; for the *first time* in the serial history of animal life, an *air-breathing* being is introduced on the stage. Nature surmounts all difficulties by adroitly resorting to an unexpected but matchless variation of her former plan; all at once, and without apparent reason, a new and extraordinary system of organs is contrived; an exquisite apparatus of *aëriferous vessels* is so skilfully blended with all the other and normal constituents of the living body, that an *air*-breathing animal results without deformity of exterior contour: in a small space a large result is realized. An insect is a diminutive animal; its muscular and nervous systems are intensely active; its fluids are highly corpusculated and fibrinized; a considerable proportion of oxygen is absolutely essential. Could it by any other expedient have been adequately supplied? But the simple distribution of patulous tracheæ throughout all the structures of the body, by which air is rather brought to the blood than blood to the air, would most imperfectly accomplish the great function of breathing. It was not enough to provide an elastic inimitable spiral, by which the passive patency of each tube is maintained. Such property as that of physical elasticity in a structure so singularly beautiful answers *another* end; it *recoils* on the *contracting* of the tube. The *contracting* of the tracheæ is in the insect the act of *ex*spiration; by this act the diameter of the tubes of the universal tracheary system is diminished, and the air is driven out through the spiracular orifices: this act is *rythmically* followed by that of *in*spiration, in which the physical elasticity of the spiral, by rebound, restores the tube to its former diameter*. No part of the circulating system but the dorsal vessel is capable of contracting and dilating. This

* I have diligently sought for the announcement of this fact amongst the varied and excellent writings of Mr. Newport, M. E. Blanchard, and M. Léon Dufour. No allusion whatever is anywhere made to this property of *rythmic* contraction and dilatation, which I have proved, by *repeated* observations on larvæ and adult insects and Myriapods, the tracheæ to possess. The omission is the more surprising, since, *without* such a property, the tracheary system would be *mechanically imperfect* as an apparatus of respiration. As the *vessels* do not contract, there would be no provision for renewing the air in the extremes of the system. The working of the general muscles of the body external to the system would obviously prove a most imperfect substitute. What is denied indeed to the vessels is conferred on the tracheæ. I cannot *prove* that the parietes of the tracheæ are capable of *originating* this movement. I cannot demonstrate them to be muscular. It is possible that the opening and shutting of the air-tubes may only follow from those alternate acts of contraction and dilatation in the abdominal segments by which the dorsal and ventral arches of the abdomen are alternately elevated and depressed like the ribs of the vertebrated animal.

fact explains an observation which the author has often made, that, considering the exalted muscular activity of the Articulata, of insects in particular, the *current of the blood in its channels moves at a disproportionately slow rate.* This diminished velocity is compensated, in the most perfect manner, by the rythmic contractility possessed by the parietes of the tracheæ. In virtue of this property the required *motion* is imparted to the *air* rather than to the *blood.* As well observed by M. E. Blanchard, the voluntary muscles of the body by their peculiar distribution *favour* the course taken by the blood, both in the arterial and venous moiety of the system. No valves exist. The mechanism of nutrition and respiration in the tracheary Articulata would be most unsuccessfully studied without the guiding knowledge of these general facts.

The characters then which distinguish an annulose from an articulate animal are more deeply graven in the interior of the organism and in its physiological actions than on the visible and exterior forms by which they are respectively characterized. There is deep meaning in the freaks of nature.

In the water-breathing Articulata the system of air-tubes just described suddenly disappears. The large size of the crustacean renders practicable the introduction of complex *branchial* organs. They accomplish that office which in the myriapod and the insect devolved upon the aëriferous tracheæ. Nature has nowhere blended the two methods of respiration in the same class. There exists no adult *water*-breathing myriapod or insect. An *air*-breathing crustacean can nowhere be found. Her plans are consistent.

One more *general* fact of organization with respect to the Articulata remains to be stated. *Nowhere* from the myriapod to the crustacean is any trace whatever to be discovered of the existence of a *true ciliary epithelium*! Why should a structure so constant and profuse in all classes *below* the Articulata so suddenly and so completely disappear at the lower limit of this class? If in the epidermic system of the articulated animal there be something incompatible with the evolution of the ciliary variety of epithelium, why should it *not* occur on the mucous? In no single instance, in any species of myriapod, insect or crustacean, on the mucous tract of the alimentary canal, or anywhere else, has any indication whatever of the presence of vibratile epithelium been ever yet discovered. This extraordinary fact cannot be arbitrary and unmeaning. Cilia are here suppressed for some reason and from some cause—what can it be? The solution should be sought in the rapid and unwonted evolution of the *muscular* system which takes place at this point. In the organism of the articulated animal there does not exist

motive force enough to sustain *two* motive systems at one and the same time: one is supplanted by the other. Ciliary is commuted into muscular motion. While studying the mechanism of respiration in the articulated animal, vibratile epithelium will therefore nowhere demand attention: its agency will be found to have been substituted by other instruments.

An exposition of the preceding general principles has seemed to the author indispensable to an intelligent study of the novel and extraordinary details, upon which it is proposed next to enter.

[To be continued.]

XV.—*Catalogue of Reptiles collected in Ceylon.*

By E. F. Kelaart, M.D., F.L.S. &c.

Order SAURIA. Lizards.

Suborder I. Leptoglossæ. Slender-tongued Lizards.

Fam. *Monitoridæ*. Monitors.

Monitor Dracæna, *Gray*.
Hydrosaurus Salvator, *Wagler*.

Fam. *Scincidæ*. The Scincs.

Riopa punctata, *Gray*.
—— Hardwickii, *Gray*.
Mabouia elegans (?), *Gray*.
Tiliqua rufescens, *Gray*.

Fam. *Acontiadæ*.

Nessia Burtoni (?), *Gray*.
Acontias (?) Layardi, n. s., *nobis*.

Fam. *Typhlopsidæ*. Typhlops.

Argyrophis Bramicus, *Daud*. *Two varieties; one with a pale white streak beneath.

Fam. *Uropeltidæ*. Rough-tails.

Uropeltis grandis, n. s., *nobis*.
—— Saffragamus, n. s., *nobis*.
—— pardalis, n. s. *nobis*.
Rhinophis (?) Blythii, n. s., *nobis*.
Siluboura Ceylonicus, *Gray*.
Dapatnaya Lankadivana, n. s., *nobis*.
—— Trevelyanii, n. s., *nobis*.